58th Petersen Asphalt Research Conference

A Virtual On-Line Event
From Laramie, Wyoming

July 13-16, 2021

www.petersenasphaltconference.org

Western Research
INSTITUTE

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WELCOME

Welcome and Bienvenue!

To the 58th Petersen Asphalt Research Conference online! As PARC chairman, I invite you to soak up some electronic hospitality! Instead of gathering in our unique city of Laramie, Wyoming, we are again conducting this conference online. Like last year, we are confident that we will maintain some of the same warm atmosphere that you've come to expect! We will continue igniting new friendships, exploring cutting edge ideas, and discovering new approaches in the constant quest for knowledge and answers.

PARC 2021 presenters from across the continent and the globe are ready to share their recent findings, representing a wide cross-section of asphalt/bitumen stakeholders. Scientists, engineers, and manufacturers are all bringing this research from the lab into production and construction in the hope of long term impacts on essential materials such as roofing and pavement. A record high of 60 abstracts were submitted and 48 selected for presentation on a 4-day format!

As THE widely recognized forum for research in progress, PARC 2021 is proud to offer a number of presentations on Rheological and Failure Performance Indices, Plastic and Pavement Recycling Combined with Recycling Agents, Asphalt Mixture Evaluation, Polymer-Modified Asphalts, Advancements in Asphalt Chemistry and Structure Characterization and Understanding, and Progress in Machine Learning Applications. All of which can be summarized in two words: "Chemistry Matters" as Dr. Claine Petersen, conference founder, used to say. Claine passed away earlier this year at age 96: this conference is dedicated to him and will include a tribute session on cutting edge "out of the box" ideas, with testimonies from some of his long time friends.

Rapidly changing circumstances around the world request and trigger innovative solutions to address increasingly complicated issues and challenges. With the development of new relevant models, analytical tools, and testing methods, cost-effective solutions with lower environmental impact contribute to address continuing concerns at all levels: global, continental, national, regional, local, and personal.

Home to the University of Wyoming, Laramie enjoys an atmosphere of active curiosity. As the university motto says "The World Needs More Cowboys", this year's conference offers a range of opportunities to venture out into new territory to bring fresh ideas and innovative solutions to reality. To anchor them into the present and the future, we are also pleased to announce that Energy & Fuels will offer the possibility to submit papers based on the abstracts and presentations made at the conference, providing they have the chemistry flavor required for this ACS publication. While PARC 2021 cannot offer its usual western outdoor adventures, we look forward to sharing these with you again in 2022.

Thank you for attending! We want to make sure to offer our gratitude and our thanks to all of the sponsors and exhibitors who help make this online conference possible. Your thoughts matter: please be sure to answer the survey that you will be sent after the conference so that 2022 be an even better experience.

We look forward to interacting with you during the virtual 2021 Petersen Asphalt Research Conference!

Jean-Pascal (JP) Planche
CEO and Senior Vice President, Asphalt and Petroleum Technologies
Western Research Institute
Laramie, Wyoming

Dr. Joseph Claine Petersen
February 14, 1925—March 11, 2021

Special Tribute Session
Tuesday July 13th at 12:30 P.M. (MDT)

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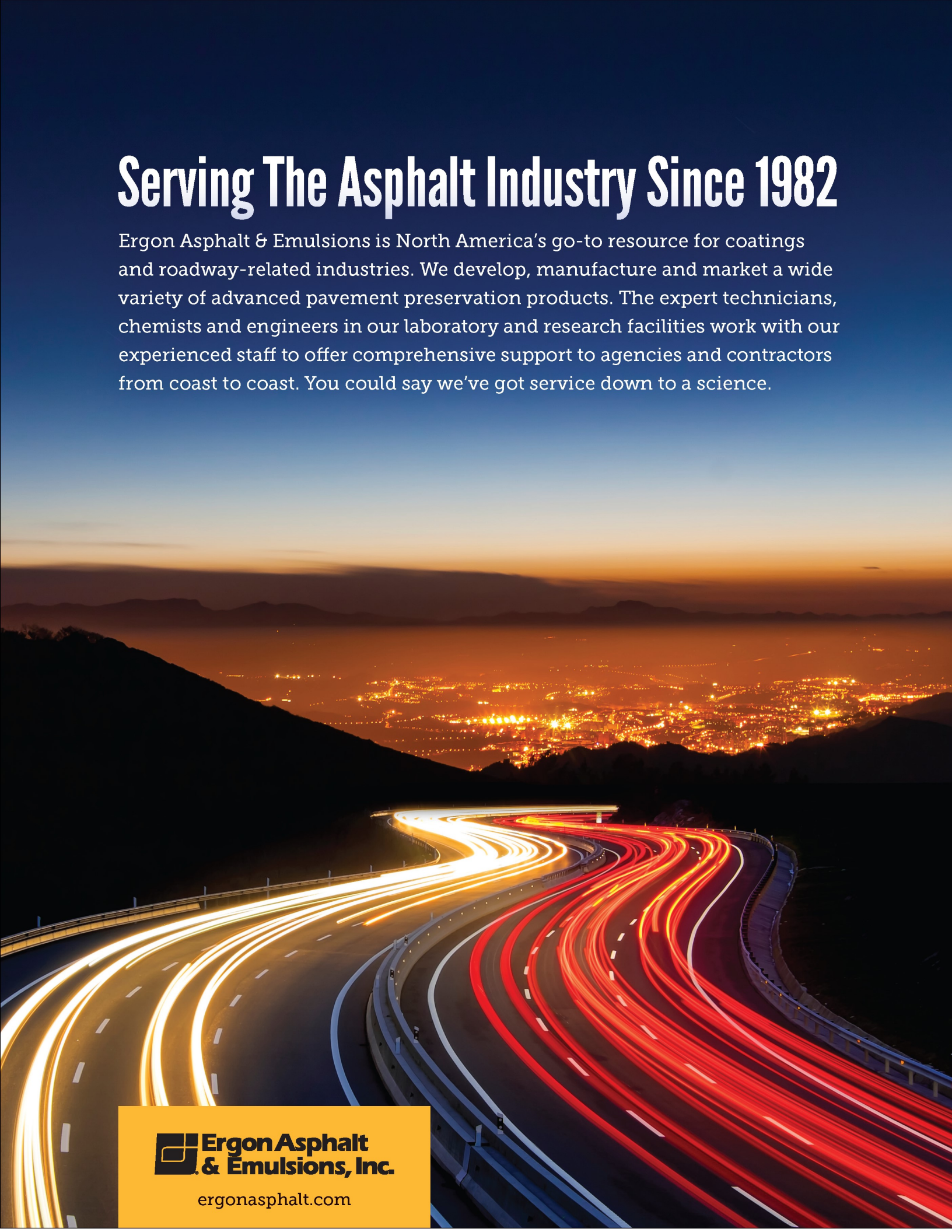

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58th Petersen Asphalt Research Conference

Conference Agenda

Tuesday, July 13

8:00AM	Welcoming & Opening Remarks	

Session 1 - Pavement Performance

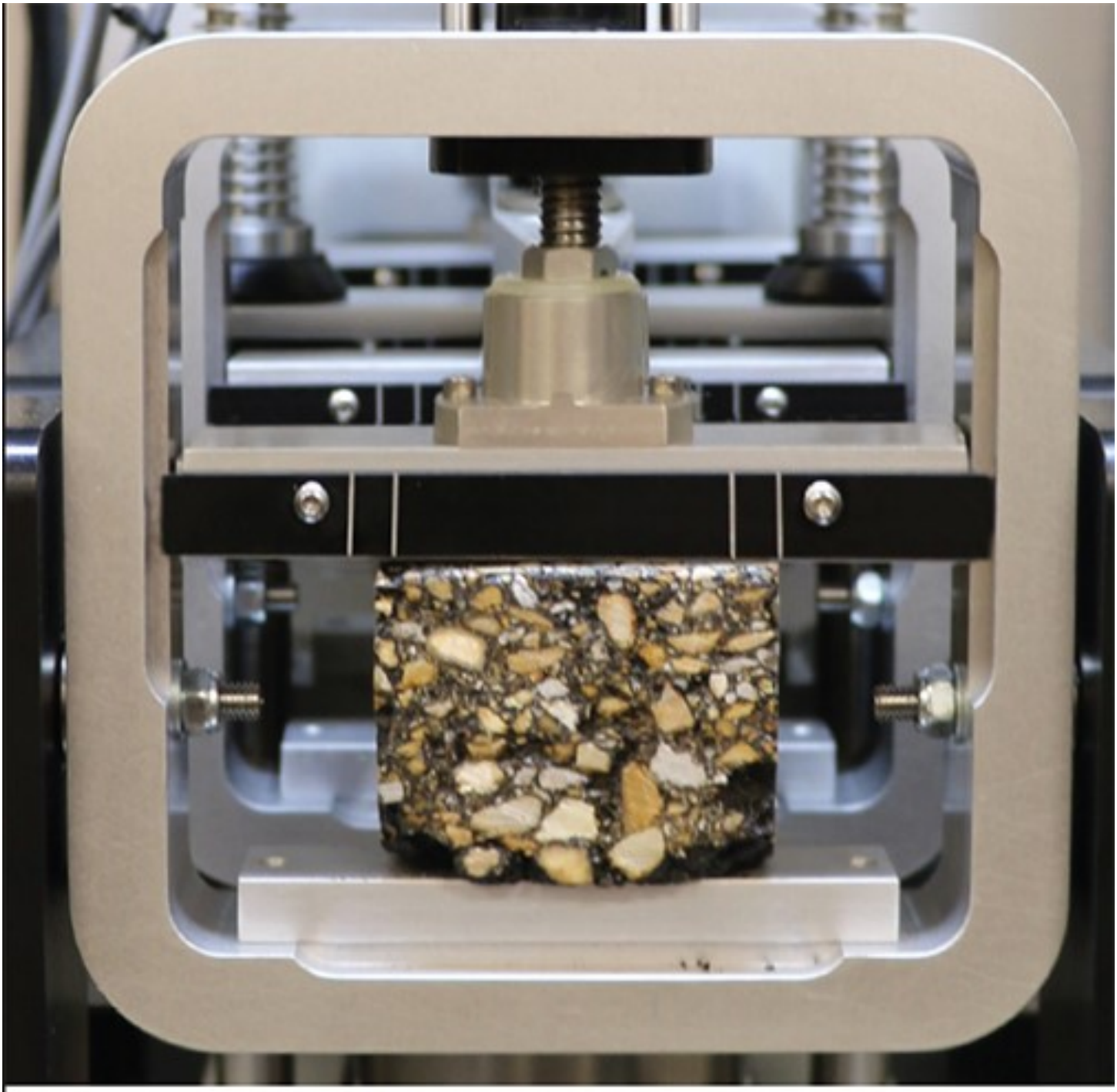
8:05AM	Rheological and Chemical Properties of Field-Aged Binders	Xavier Carbonneau *Colas* Hilde Soenen *Nynas*
8:30AM	Impact of Binder Acidity Index on the Properties of Asphalt Mixes Incorporating Additives	Dr. Fayçal Lahjiri *Eurovia*
8:55AM	Another Look: Texas Freeze-Thaw Pedestal Data Using Life Distribution Analysis	Richard Steger *Ingevity*
9:20AM	Impact of Long-Term Aging on the Cracking Performance of Asphalt Mixtures Containing RAP & RAS at a Full-Scale Pavement Facility	Dr. Michael Elwardany *Engineering & Software Consultants, Inc.*
9:45am	**Break for Exhibitors**	
10:15AM	Quantifying Impacts of Long-Term Field Aging on Asphalt Binders in Illinois	Punit Singhvi *University of Illinois Urbana Champaign*
10:40AM	Physicochemical Correlations of Short and Long Term Aged Asphalt Mixtures for Low Temperature Performance	Abdullahal Mamun *Department of Civil and Environmental Engineering, University of Utah*
11:05AM	An Update from FHWA on AI Application Methods for Asphalt Binder and Mixture Performance	Dr. Adel Rezaei Tarahomi *National Academy of Sciences, Engineering, and Medicine*
11:30AM	Determination of a Provisional Structural Layer Coefficient for an Aramid Synthetic Fiber Modified Asphalt Mixture	Dr. Fan Yin *National Center for Asphalt Technology at Auburn University*
NOON	**Break for Exhibitors**	

58th Petersen Asphalt Research Conference

Conference Agenda

12:30PM **Dr. Claine Petersen Tribute & Honorary Session**

12:55PM	Accelerated Aging of Loose Asphalt Mixtures Using Ozone and Other Reactive Oxygen Species	Dr. Anand Sreeram *University of Texas at Austin*
1:20PM	Molecular Comparison, Yield, and Toxicity of Photogenerated DOM from Coal Tar- and Petroleum-derived Asphalt Sealants	Taylor J. Glattke *Florida State University - Department of Chemistry and Biochemistry & National High Magnetic Field Laboratory - ICR Program*
1:45PM	Digestion of Unconventional Materials to Make Asphalt Recycling Additives	Dr. Jeramie Adams *Western Research Institute*
2:10PM	Progress Toward Designing More Resilient Asphalt Pavements	Dr. Amir Golalipour, P.E. & Dr. Heather Dylla *Federal Highway Administration*



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Conference Agenda

Wednesday, July 14

Session 2 - Chemistry & Chemical Modification

8:05AM-9:45AM	**Guest Moderator**	**Dr. Michael Elwardany** ***Engineering & Software Consultants, LLC.***
8:05AM	Effects of Size and Shape of Asphaltenes on Asphalt Binder Properties	Dr. Yuhong Wang *Department of Civil and Environmental Engineering, Hong Kong Polytechnic University*
8:30AM	Dielectric Spectroscopy: Application for Paving Grade Bitumen	Dr. Dawid D'Melo *Shell India Markets Pvt. Ltd.* Richard Taylor *Shell International Petroleum Co Ltd*
8:55AM	Sustainable Road Construction with Novel Chemical Additive for Binder Modification: An Overview of the Latest Research	Nicolás Carreño *Institute of Highway Engineering of the RWTH Aachen University* *Dr. Olivier Fleischel BASF SE, Ludwigshafen, Germany*
9:15AM	Bitumen (Asphalt) Beyond Oil	Frank H.W. Albrecht *ALBR3CHT Supply Concepts GmbH*
9:45AM	**Break for Exhibitors**	
10:15AM	New Performance-Related Specifications for Latex-modified Bitumen Emulsions	Juliette Parisot & Thomas Lebarbé *Eurovia*
10:40AM	A Hybrid Reactive Isocyanate Based Modifier (B2Last®)+ SBS Modified Asphalt Binder for Longer Lasting Asphalt Pavements	Dr. Nam Tran *National Center for Asphalt Technology at Auburn University*
11:05AM	Evaluation of Properties and Performance of Modified Asphalt Binders and Mixtures with Reactive Isocyanate and SBS	Danial Mirzaiyanrajeh, *University of New Hampshire*
11:30AM	Base-Binder-Dependent Reactivity in Epoxy-Modified Asphalts (EMA) for Durable Open-Graded Friction Course (OGFC)	Dr. Michael Elwardany *Engineering & Software Consultants, Inc.*
NOON	**Break for Exhibitors**	

58th Petersen Asphalt Research Conference

Conference Agenda

12:30AM-2:35PM	**Guest Moderator**	**Dr. Raquel Moraes** ***National Center for Asphalt Technology at Auburn University***
12:30PM	Atomic Force Microscopic Imaging and Role of Reactive Isocyanate-Based Modifications on SBS Modified Asphalt Improving Thermal Stability and Mechanical Performance	Eesha Khare *MIT-LAMM*
12:55PM	Fractionation and Characterization of Asphalt Using Advanced Mass Spectrometry Techniques in Conjunction with NMR and IR Characterization	Junho Jeon *Dow Inc.*
1:20PM	Evaluation of the Relationship between Rheological Properties and Functional Group Indices for Asphalt Binders from Mixtures Treated with Recycling Agents (RA)	Gerald Reinke *MTE Services Inc.*
1:45PM	Evaluation of Bio-Based Recycling Agents	Dr. Raquel Moraes *National Center for Asphalt Technology at Auburn University*
2:10PM	The Use of Soybean Oil-Derived Modifiers for Improving the Properties of Asphalt Pavements	Dr. Ali Arabzadeh *Iowa State University*


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Conference Agenda

Thursday, July 15

Session 3 - Physical Testing & Characterization

8:05AM	Performance Testing of Asphalt Mastic	Dr. Johannes Büchner *Braunschweig Pavement Engineering Centre (ISBS), TU Braunschweig*
8:30AM	Highlighting the Potential of the Phase Angle Master Curve Through Multivariate Statistical Analyses for Clustering Aged Asphalt Binders	Rodrigo Shigueiro Siroma *Université Gustave Eiffel*
8:55AM	X-Ray Tomography Imaging of the Pore Structure and Acoustical Properties of Low-Noise Semi-Dense Asphalt Field Samples	Dr. Peter Mikhailenko *Empa*
9:20AM	Nanoscale Local Thermal Analysis of Bitumen Surface Microstructures	Dr. Farrokh Tarpoudi Bahri *Empa & Laboratory of Thermodynamics in Emerging Technologies, Department of Mechanical and Process Engineering, ETH Zurich*
9:45AM	**Break for Exhibitors**	
10:15AM	Aging Evaluation of Asphalt Recycling Agents for Hot Mix Asphalt – An Interlaboratory Study	Dr. Augusto Cannone Falchetto *Aalto University*
10:40AM	Accelerated Pavement Weathering System (APWS)	Dr. Gaylon Baumgardner *Paragon Technical Services, Inc.*
11:05AM	A New Rapid DSR Separation Method for Polymer Modified Asphalt	Dr. Yuanchen (Simon) Cui *U.S. Polyco*
11:30AM	Thermally Induced Internal Cracking in Asphalt Mixtures – Validation and Prediction of Low Temperature Performance	Sang Soo Kim *EZ Asphalt Technology, LLC.*
NOON	**Break for Exhibitors**	

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Conference Agenda

12:30AM-2:35PM	**Guest Moderator**	**Dr. Geoffrey Rowe** ***Abatech Inc.***
12:30PM	What Doesn't Kill Asphalt, Makes it Stronger	Dr. Jean-Pascal Planche *Western Research Institute*
12:55PM	Evaluation of Crossover Temperature and Aging Ratios to Evaluate Cracking of Binders	Dr. John D'Angelo *D'Angelo Consulting, LLC*
1:20PM	Cracking Parameters of Asphalt Binders with Softener Modifiers	Javier J. García Mainieri *Illinois Center for Transportation, University of Illinois at Urbana-Champaign*
1:45PM	Automatic Pavement Condition Evaluation and Map Visualization (Case Study in Missouri)	Dr. Hamed Majidifard, *University of Missouri*
2:10PM	When Superpave Doesn't Work	Dr. Bob Kluttz *Kraton Polymers*

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Conference Agenda

Friday, July 16

Session 4 - Plastics & Recycling

8:05AM	Morphology and Rheology of Asphalt Binders Modified With Different Amount of the PE/SBR Thermoplastic Volcanized Polymer	Dr. Mohammad Zia Alavi *School of Civil Engineering, University of Tehran*
8:30AM	Dry-Process Recycled Plastics Modified (RPM) Asphalt Mixture Design and Performance Evaluation	Jean-Paul Fort *COLAS USA* Dr. Fan Yin *National Center for Asphalt Technology at Auburn University*
8:55AM	Use of a Chemically Modified Recycled Plastic Additive for Asphalt Modification	Dr. Fan Yin *National Center for Asphalt Technology at Auburn University*
9:20AM	Binder and Mix Performance of Wet Process Polyethylene-rich Recycle Streams with an RET Compatibilizer	Dr. C.J. DuBois *Dow Inc.*
9:45AM	**Break for Exhibitors**	
10:15AM	Effect of Reactive Ethylene Terpolymer on Recycled Polyethylene Modified Asphalt Binder and Mixture	Helmut Leodarta *University of Missouri-Columbia*
10:40AM	Deconvolution Analysis of Glass Transition Response to Aging and Rejuvenation	Dr. Hassan Tabatabaee *Cargill*
11:05AM	Characterizing the Aging of Asphalt Binder Containing Recycled Materials Through Rheological and Chemical Analysis	Mohammad Rahman *University of California Pavement Research Center, Department of Civil and Environmental Engineering, UC Davis*
11:30AM	Field Study of Sustainable High Performance Engineered Asphalt Concrete Mixtures	Phil Blankenship *Blankenship Asphalt Tech and Training, PLLC.*
11:55AM	Critical Review of the Properties of the Recovered ALF binders and the Connections with Pavement Performance: Six Years of In-situ Aging in the Presence of RAP and RAS.	Adrian Andriescu *SES Group & Associates, LLC .*
12:20PM	Closing Remarks	

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Session 1 - Pavement Performance

Rheological and Chemical Properties of Field-Aged Binders

Xavier Carbonneau | *Colas*
Hilda Soenen, X. Lu, & C. Robertus | *Nynas*

Fourteen old pavement sections, between 8 and 21 years in service, have been studied. Asphalt cores from the wearing courses were cut into slices to follow the aging evolution with pavement depth. Binders were recovered and analyzed for all layers to determine some of the recent rheological parameters proposed to explain on-site behavior. Test results, slice by slice from top to bottom, have been compared to existing published thresholds. It was not possible to compare these to the initial binder characteristics, as these rheological tests were not common practice at the time of paving of the different sections. Possible correlations between the composition, determined by SARA analysis, and rheological characteristics have been examined. The state of damage of the wearing course has also been compared to results on binders. Even if some trends are confirmed defining critical threshold values remains difficult. Differences between the top and bottom slices lead to questions the existing thresholds proposed for G-R and delta Tc, as these results can be on both sides of the critical values. Some significant differences between laboratory aging and evolution on-site are also assumed.

Impact of Binder Acidity Index on the Properties of Asphalt Mixes Incorporating Additives

Fayçal Lahjiri, Frédéric Delfosse, Jacques-Antoine Decamps, Thomas Lebarbé, Sabine Gazeau | *Eurovia Management*

Durability of asphalt mixes is often reduced to the evolution of their thermomechanical properties during the aging process. However, the environment of an asphalt mix is also described with the climatic phenomena that it can undergo, such as rains for example. They must be considered in the evaluation of the durability of an asphalt mix, especially when it is located on the most exposed layer, the wearing course. Indeed, water is considered as an aggressive agent that can lead to dewetting by shrinking the bitumen film on the surface of the aggregates. Due to the hydrophobic characteristic of bitumen, studies described in the scientific literature mainly focus on adhesion problems and on the behavior with respect to freezing and thawing phenomena. However, the introduction in the bitumen of various agents (recycling agents, adhesiveness dopes...) of variable chemical nature and polarity can lead to effects induced by chemical reactions to be differentiated from adhesivity. The objective of this work is to better describe the potential effects that these binders, which cannot be entirely considered as hydrophobic, can generate at the asphalt mix scale.

Session 1 - Pavement Performance

Another Look: Texas Freeze-Thaw Pedestal Data Using Life Distribution Analysis

Jason Bausano & Richard Steger | ***Ingevity***

Moisture damage in asphalt pavements is a complex problem involving chemistry of the aggregate, asphalt, and interaction of the two. Moisture damage has been researched for 30+ years by universities, agencies, and private companies. SHRP Report A-646 and A-341 contain a wealth of chemistry data on asphalt and aggregate along with mixture data in the form of cycles to failure via Texas Freeze-Thaw Pedestal Test. Since these reports were published in 1993, many advancements have been made in statistics and statistical software packages. This paper's objective is to illustrate the use of life data analysis (life distribution analysis) in modeling the time to failure of the mixture based on eight asphalt and eleven aggregate totaling 88 combinations . For example, one can observe failure rates over time to predict when a mixture might fail based on a specific asphalt or aggregate chemistry. Some observations (12 of 88) survived the 50-cycle limit (censored) without failure. This analysis technique allows use of censored data when time observations are not fully known. Mix designers can use this probabilistic tool to determine if moisture damage is going to be problem in their mixture based on the chemistry of the aggregate and asphalt.

Impact of Long-term Aging on the Cracking Performance of Asphalt Mixtures Containing RAP and RAS at A Full-Scale Pavement Facility

Michael Elwardany & Varun Veginati | ***Engineering & Software Consultants, Inc.***
David Mensching | ***FHWA***

Oxidative aging causes asphalt binders and mixtures to stiffen and embrittle, which leads to a high potential for cracking in asphalt concrete and, by extension, asphalt pavements. Recently, NCHRP 09-54 proposed a long-term aging protocol in the laboratory for performance testing and prediction of asphalt mixtures. The new protocol involves long-term aging of loose mixtures in oven at 95°C and for durations determined based on a newly-developed pavement aging kinetics model, Climatic Aging Index (CAI), and aging duration maps. At FHWA's Turner-Fairbank Highway Research Center, five plant-produced asphalt mixtures with various RAP or RAS contents from Accelerated Load Facility (ALF) lanes were tested after short-term aging, long-term oven aging for 5 days at 85°C, 3 days at 95°C, and for 8 hours at 135°C. Kinetics modeling was used to find the corresponding field climate, age, and depth for these aging conditions. For instance, loose mix aging for 3 days at 95°C corresponds to field aging in McLean, VA climate at 20mm below the pavement surface after 8 years of service-life. Mixtures were tested using indirect tension (IDEAL-CT), semi-circular beam (I-FIT), and the uniaxial cyclic fatigue tests at intermediate temperatures. Results from this study provide important insights on the long-term aging and cracking susceptibility of RAP/RAS mixtures as well as the relative sensitivity of the various cracking test methods to long-term aging and RAP/RAS contents.

Session 1 - Pavement Performance

Quantifying Impacts of Long-Term Field Aging on Asphalt Binders in Illinois

Punit Singhvi, Javier J. García Mainieri, Brajendra K. Sharma, & Imad L. Al-Qadi | ***University of Illinois Urbana Champaign***
Hasan Ozer | ***Arizona State University***

Asphalt binder's aging could result in asphalt concrete (AC) pavement cracking. Quantifying the extent of binder aging is important to formulate and select proper binder to ensure pavement performance. Factors affecting binder aging, and therefore its rheology, include temperature, ultra-violet radiation, in-place AC density, and binder chemistry. The objective of this study was to identify a laboratory aging protocol that represents realistic field aging in Illinois. To accomplish this objective, binders were extracted from field cores, aged eight to thirty-one years, and their rheology and chemistry were determined. Small- and large-strain rheological parameters were established. In addition, chemical functional groups and molecular weight distribution of extracted binders were evaluated. Effect of aging across pavement depth was also investigated. Rheological testing parameters showed that single pressure aging vessel (PAV) conditioning might not represent the extent of field aging. However, double PAV conditioning was found to resemble 10-15 years of AC pavement service life in Illinois. Thresholds are proposed for selected small- and large-strain rheological parameters that could be used for binder selection to ensure AC pavement long-term performance. Furthermore, chemical analysis of extracted binders showed that specific carbonyl functional groups were affected by field aging.

Physicochemical Correlations of Short- and Long-Term Aged Asphalt Mixtures for Low Temperature Performance

Rizwanur Rahman, Abu Sufian Mohammad Asib, Pedro Romero, Ph.D., Michael P. Hoepfner, Ph.D., & Abdullahal Mamun | ***University of Utah***

Asphalt binders are polydisperse, complex, and heteroatomic hydrocarbon molecules, which change their molecular structures due to aging. Oxidation, along with volatilization, is the major aging route to significantly alter the physical properties of the asphalt binders. A coherent understanding of physicochemical correlations is required to understand the effectiveness of asphalt binders at low temperatures as road pavement materials. However, an established relationship between asphalt's chemical characteristics and asphalt mixture's physical properties is still missing, mainly attributable to the connection gap between laboratory aging methods with field measurements. In this study, an effort has been made to establish a correlation between asphalts chemical properties change with physical characteristics alteration by investigating 32 different asphalt mixtures, aged with four different aging protocols to simulate field conditions. The chemical compositional variance of diverse functional groups within asphalt mixtures was obtained by analyzing the FTIR spectra. A bending beam rheometer was utilized to characterize the physical properties. It is found that the oxidative reduction of oxygen and sulfur influences the loss of cohesion between asphalt mastic and aggregates. Further investigation using SEM-EDX revealed microstructural damage in aged specimens. Overall, the study provides a comprehensive and feasible method to perform physicochemical characterization of asphalt mixtures.

Session 1 - Pavement Performance

An Update from FHWA on AI Application Methods for Asphalt Binder and Mixture Performance

Adel Rezaei Tarahomi | ***National Academy of Sciences, Engineering, and Medicine***
David Mensching | ***Federal Highway Administration***
Raj Dongre | ***Dongre Laboratory Services Inc.***

Emerging advanced data and computer science techniques give the ability to engineers to solve challenging problems through new computational algorithms. Nowadays, artificial intelligence (AI) is used in pavement engineering subjects like analysis, management, maintenance, and design. However, additional research is required to address critical topics and conventional methods' weaknesses used in this field for decades. This study presents some of the machine learning (ML) applications in asphalt binder and mixture performance and performance grading (PG) prediction developed at FHWA. Also, an AI dashboard was developed that facilitates access to the pre-trained ML models by which engineers and scholars can use for testing or using the models in their studies.

The prediction results show that using the newest machine learning algorithms like XGBoost can significantly improve the accuracy of predicting the shear modulus and dynamic modulus compared to the traditional prediction models. Also, this study shows that using ML in predicting the PG of binders is very promising and may help to reduce the cumbersome process in the lab. Finally, ongoing FHWA projects FHWA are presented to show how advanced techniques, using data collected through the years, can reduce the burden of laboratory tests and consequently save time and materials.

Determination of a Provisional Structural Layer Coefficient for an Aramid Synthetic Fiber Modified Asphalt Mixture

Dr. David Timm | ***Auburn University***
Dr. Fan Yin, Mr. Adam Taylor, & Dr. Buzz Powell | ***NCAT***

Most of the state highway agencies that currently use the '93/'98 AASHTO method for pavement structural design utilize the 0.44 layer coefficient that was originally recommended by the AASHO Road Test in the 1950's. However, several existing studies have shown that adding aramid synthetic fibers (ASF) can potentially improve the structural capacity of asphalt mixtures due to fiber reinforcement. This improvement may lead to a higher structural coefficient and a reduced asphalt layer thickness, providing significant cost savings for pavement construction. The objective of this study was to determine a structural layer coefficient for an ASF modified asphalt mixture using FORTA-FI®. The study was primarily based on laboratory testing and theoretical structural pavement analysis and design. Two plant-produced mixes were sampled and tested for laboratory performance characterization. The control mixture used a performance graded (PG) 76-22 styrene-butadiene-styrene (SBS) modified binder, while the experimental mixture was produced with ASF in addition to the same PG 76-22 SBS modified binder. Adding ASF was found to increase fatigue performance at field strain levels by a factor of five or six, which resulted in a twenty percent increase in layer coefficient.

Session 1 - Pavement Performance

Accelerated Aging of Loose Asphalt Mixtures using Ozone and Other Reactive Oxygen Species

Anand Sreeram, Ahmad Masad, Zahra Nia, & Amit Bhasin | ***University of Texas at Austin***
Bernhard Hofko, Johannes Mirwald, & Daniel Maschauer | ***TU Wien***

Efficient and practical techniques to simulate aging of asphalt mixtures is a focus area for practitioners around the world. In this study, a laboratory procedure was developed for accelerated aging of loose asphalt specimens using highly oxidative gas consisting of two types of reactive oxygen species (ROS) i.e., ozone (O3) and nitrogen oxides (NOx). The procedure involved the aging of loose mixtures in an enclosed ROS rich environment for a period of 1 day at 95oC. The chemical and rheological properties of the extracted binders from 5 different mixtures aged using this method were then compared to analogous binders aged using a benchmark of loose mixture aging at 95oC for 5 days in a laboratory oven. Different metrics for oxidation and aging were comprehensively evaluated including extent of oxidative groups by Fourier transform infrared spectroscopy (FTIR), high and low temperature rheological properties using dynamic shear rheometer (DSR), and polarity based chemical fractionation into saturates, aromatics, resin and asphaltene (SARA) fractions. Favorable chemo-mechanical correlations were obtained from the results which confirmed that the mixtures aged using the ROS aging method showed similar or higher levels of aging just after 24 hours when compared to the conventional 5-day aging method.

Molecular Comparison, Yield, and Toxicity of Photogenerated DOM from Coal Tar- and Petroleum -derived Asphalt Sealants

Taylor J. Glattke, Alan G. Marshall, & Ryan P. Rodgers | ***FSU - Dept. of Chemistry and Biochemistry & National High Magnetic Field Laboratory - ICR Program***
Martha L. Chacón-Patiño | ***National High Magnetic Field Laboratory - ICR Program***
Sarajeen Saima Hoque | ***FAMU-FSU Dept. of Civil and Environmental Engineering***
Thomas E. Ennis | ***Watershed Protection Dept. City of Austin, TX***
Steven Greason | ***Sitelab Corporation***

Coal tar-based products, specifically coal tar road sealant, contain high amounts of polycyclic aromatic hydrocarbons (PAHs), known human carcinogens, that also adversely affect organisms in aquatic ecosystems. Thus, these products remain an environmental concern. This work compares oil- and water-soluble photoproducts that result from photoirradiation of two road sealants with different chemical compositions: asphalt-based and coal tar-based. Ultrahigh resolution Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS) was used to determine molecular composition of the unirradiated sealants and their photoproducts. Dissolved organic carbon analysis and Microtox Bioassay were utilized to determine the amount of carbon leached into water and the overall toxicity of the water-soluble species. The results revealed that asphalt sealant produces few toxic water-soluble species which have compositions similar to natural dissolved organic matter. Conversely, coal tar sealant contains high amounts of PAHs and its water-soluble photoproducts have high abundances of oxidized PAHs with high associated toxicity. The results indicate the potential harmful effects of coal tar-based products in the environment and public health, and support the use of less detrimental, petroleum-derived products. Work supported by the NSF Cooperative Agreement DMR-1644779 and the State of Florida.

Session 1 - Pavement Performance

Digestion of Unconventional Materials to Make Asphalt Recycling Additives

Dr. Jeramie Adams | *Western Research Institute*

Coal and wind turbine blades are unconventional materials for producing asphalt additives. Subbituminous coal reserves in Wyoming are about 42 billion tons and utilization of this feedstock for thermal energy has been declining over the last decade, and it is projected to continue its significant decline into the future. Subbituminous coal contains many oxygen functional groups amenable to follow-on chemistry, as well as low amounts of carcinogenic polycyclic aromatic hydrocarbons (PAHs), especially compared to more mature coals. Wind turbine blades, on the other hand, are highly engineered composites consisting of mainly fibers and epoxy and they must be replaced every 10-15 years. These large blades are currently landfilled, or backfilled into coal mines for reclamation purposes. Like subbituminous coal, wind turbine blades are a special, although different, issue for Wyoming since blades from across the country are finding their way into the state, and the state also has several wind farms, in service, in development or in the plans. By utilizing thermochemical methods to selectively digest these materials, desired properties can be infused to produce novel additives that can soften asphalt for recycling or improving its cracking resistance. Asphalt is the most recycled material in the world and it will continue to be recycled well into the future. Recycling higher amounts (>30 wt%) of reclaimed asphalt pavement (RAP) often requires the use of softening agents/additives, and the use of these additives is steadily growing. Furthermore, the digestion and chemical modification of subbituminous coal, and wind turbine blade extracts, can be achieved using other chemical feedstocks from renewable carbon sources, such as fatty acids, fatty alcohols and fatty amines. Using renewable carbon feedstocks helps to further reduce environmental impacts and contributes to a more circular economy. These concepts will be explained in more detail and some examples from coal and wind turbine blade additives will be shown.

Progress Toward Designing More Resilient Asphalt Pavements

Heather Dylla, Ph.D. | *Federal Highway Administration*

Extreme weather, increased temperatures, and sea level rise threaten investments in transportation infrastructure. Hence, pavement resilience is becoming an increasing critical consideration for highway and transportation engineers. National efforts towards more resilient pavements begins with a documented commitment and policies. FHWA issued Order 5520: Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events to establish FHWA policy and responsibilities. The order serves to establish FHWA's policy and approach to addressing these risks.

This study is focused on the adaptation strategies and incorporation of resilience in pavement design, construction, maintenance and preservation processes. This presentation will include highlights from some of the recent FHWA activities on pavement resilience. Results of two case studies from Transportation Engineering Approaches to Climate Resiliency (TEACR) projects with focus on temperature and precipitation impacts on asphalt pavements will be presented. Furthermore, major findings from FHWA Pavement Resilience peer exchange conducted in the last quarter of 2020, will be discussed. Lastly, upcoming FHWA projects on pavement resilience will be highlighted.


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Session 2 - Chemistry & Chemical Modicication

Effects of Size and Shape of Asphaltenes on Asphalt Binder Properties

Yuhong Wang, Kecheng Zhao, Fangjin Li, & Kin Ming Chan | ***Department of Civil and Environmental Engineering, Hong Kong Polytechnic University***

The size and shape of asphaltenes in asphalt binders were difficult to be obtained in the past. In this study, a new method was developed to directly observe asphaltene microstructures in asphalt binders. No solvent casting was used in sample preparation; hence, the natural state of the asphaltenes was preserved. Asphaltene particles were also separated and examined for their morphology and toughness. The impacts of asphaltene content and morphology on some performance-related properties of asphalt binders were investigated. Asphalt binders of different aging states from different locations of the world were used for analysis, including those used in the SHRP program. The analysis revealed that asphaltenes in non-aged asphalt are generally well disbursed, with occasional formation of large agglomerates, and both the size of asphaltenes and the likelihood of the agglomerates depend on asphalt source. Rod-shaped, crystal-like asphaltene particles were found in both artificially-aged and field-aged asphalt binders. Test results indicate that asphaltene content plays a predominant role in determining relative ZSV (ratio between the system ZSV and the liquid phase ZSV), and asphaltene morphology likely plays a secondary role. Conversely, both the content and morphology of asphaltenes likely play major roles in determining the derived ductility of asphalt.

Dielectric Spectroscopy: Application for Paving Grade Bitumen

Subhendu Bhattacharya & Dawid D'Melo | ***Shell India Markets Pvt. Ltd.***
Richard Taylor | ***Shell International Petroleum Co Ltd*****.**

Dielectric spectroscopy (DES) is a technique which measures the response of a material on application of an electric field. Dipoles present in the sample respond to the electric field applied by the DES. The size of the dipole and intramolecular friction between molecules influence the obtained DES spectrum. Previous work has investigated the possibility of using the DES to predict weathering behavior of blown bitumen. The present work investigates the use of the DES to predict standard properties of bitumen. Correlations between the DES response and a number of standard bitumen properties were observed. Using the DES indications on bitumen properties are possible from a single specimen measurement. The DES could potentially be used as a tool to rapidly assess bitumen properties or could be used as a research tool to bridge the gap in correlating bitumen chemistry and rheological properties. More work is required to refine the correlations between bitumen properties and the DES spectrum as well as using the DES to increase understanding on chemical factors which drive bitumen properties.

Session 2 - Chemistry & Chemical Modicication

Sustainable Road Construction with Novel Chemical Additive for Binder Modification: An Overview of the Latest Research

Nicolás Carreño & Dr. Markus Oeser | ***Institute of Highway Engineering of the RWTH Aachen University, Aachen, Germany***
Dr. Olivier Fleischel | ***BASF SE, Ludwigshafen, Germany***

A novel chemical additive for binder modification has been developed by BASF and tested at the laboratory of the Highway Engineering Institute of the RWHT Aachen in Germany. The additive has demonstrated to provide excellent workability as well as performance benefits for the asphalt mixtures. Laboratory tests, in addition to real large-scale trials, have shown that this particular additive can improve the affinity/adhesion between binder and aggregates, enabling a temperature reduction during production and construction of asphalt mixtures while increasing the performance against rutting and fatigue failure, keeping the low temperature properties of the mixture unaffected. The additive, which is based on isocyanate chemistry, reacts within the constituents of the binder, generating a crosslinking polymeric network. The reaction works particularly well with mixture containing a high amount of reclaimed asphalt, due to the increased functional groups of the aged asphalt binder. Several sections have been successfully paved in Germany using this new modifier, proving it can be a suitable solution for sustainable road construction. Such modified pavement will withstand the increase in traffic and climatic conditions to which roads are being subjected to.

Bitumen (Asphalt) Beyond Oil

Frank H.W. Albrecht | ***ALBR3CHT Supply Concepts GmbH***

We have reverse engineered bitumen (asphalt) from natural and bio waste sources and developed a new, decentralized and disruptive technology to produce 100% bio bitumen. We start from the two building blocks of bitumen, being asphaltenes and maltenes, which are supplied separately as a coarse powder (asphaltenes) and a liquid (maltenes). The two components do not require any heating during transport and storage, are both non-mineral oil products and are therefore not constrained in use by the limiting factors which come with conventional bitumen logistics. In order to make bitumen the two components are blended with each other according to the instant coffee principle or alternatively can form bitumen in situ in the pugmill of the hot mix plant, while the blending ratio between the two determine the initial PG grade. A further addition of a cold liquid polymer will allow a whole range of possible PG grades and different UTI's.

Session 2 - Chemistry & Chemical Modicication

New Performance-Related Specifications for Latex-Modified Bitumen Emulsions

Juliette Parisot, Thomas Lebarbé, & Frédéric Delfosse | *Eurovia*

Bitumen emulsion modification with latex is a common process widely utilized in the road industry. In Europe, the performances of such residual binder, obtained via NF-EN 13074/1-2, is evaluated with the standardized Pendulum Test (NF-EN 13588). Even though these well-known methods are relevant for some emulsions (e.g SBS or EVA modified emulsions), it is far less appropriate for latex-modified emulsions, particularly because of the specific microstructure formed in the residual binder.
Aware of the differences between American and European standards on this topic, this project aimed to develop performance-related methods for latex-modified emulsion inspired by the "Performance Grade" already used for bituminous binder in America, itself progressively being suited towards "Emulsion Performance Grade". This grade method notably relies on the MSCR Test which evaluates binder's performances at high service temperature to mimic rutting and bleeding.
Once fine-tune for latex-modified emulsion residue, the MSCR test disclosed relevant data on creep compliance (Jnr) and elastic recovery. As part of this study, a new latex has been developed using acrylic chemistry and MSCR Test as performances indicator. Besides excellent outdoor properties such as UV and oxidation resistance, this new acrylic latex has good performances in MSCR test, comparable to the SBR latex used hitherto in Europe.

A Hybrid Reactive Isocyanate Based Modifier (B2Last®)+SBS Modified Asphalt Binder for Longer Lasting Asphalt Pavements

Nam Tran |*NCAT*
David Timm & Megan Foshee | *Auburn University*
Brian Orr & Bernie Malonson | *BASF*

The reactive isocyanate-based monomer (B2Last) can be used by itself or with other modifiers to modify asphalt binders to meet the most demanding grades currently specified by state agencies. In this study, a PG 88-22 binder was formulated by modifying a PG 67-22 binder with 2.5% linear SBS and 2.0% B2Last. While the hybrid binder was graded with a true grade of 90.1-24.5, its viscosity was similar to that of a PG 76-22 SBS modified binder. The hybrid binder was compared to a conventional PG 76-22 SBS modified binder with approximately 3% SBS in a comprehensive laboratory evaluation. The laboratory evaluation included (a) balanced mix design using IDEAL-CT and Hamburg and (b) advanced mixture fatigue cracking characterization using dynamic modulus and cyclic fatigue. The laboratory test results were then used for structural pavement simulations, including WESLEA and FlexPAVE cracking analyses. Compared to the conventional SBS modified mixture, the hybrid modified mixture was estimated to have a 46% higher fatigue life or 12% less fatigue damage, resulting in a 4 to 10% thinner asphalt structure. The structural contribution of this mixture will be further evaluated in a field experiment at the NCAT Test Track.

Session 2 - Chemistry & Chemical Modicication

Evaluation of Properties and Performance of Modified Asphalt Binders and Mixtures with Reactive Isocyanate and SBS

Danial Mirzaiyanrajeh, Jo E. Sias, Ph.D., P.E., & Eshan V. Dave, Ph.D., | ***University of New Hampshire***
Zachary D. McKay & Phillip P. Blankenship, P.E. | ***Blankenship Asphalt Tech & Training, LLC***
Brian Orr, Jerome Jourdan, & Bernie L. Malonson | ***BASF Corporation***

This research comprehensively evaluates the benefits of modifying asphalt binders with reactive isocyanate-based modifier (RIB) and styrene-butadiene-styrene (SBS) using laboratory binder and mixture characterization. Four asphalt binders evaluated include a PG 64-22 control (neat) binder, modified asphalt binders with 2% RIB, 2% SBS, and a binder modified with the combination of 2% RIB and 2% SBS. Temperature and frequency sweep, multiple stress creep recovery (MSCR), and atomic force microscope (AFM) tests were conducted toward investigation properties and morphology of study binders. Asphalt mixtures were made from the study binders and complex modulus (E*), disk-shaped compact tension (DCT), indirect tensile creep and strength (IDT), and Hamburg wheel tracking (HWT) tests were conducted to determine the properties and performance of asphalt mixture with respect to different distresses. Based on laboratory testing results, individually the RIB and SBS modifiers improved the properties of the control asphalt binder with respect to rutting but may have a negative effect on cracking performance. Asphalt mixtures laboratory tests results strongly supported the findings based on asphalt binder laboratory results and showed binder modification with combination of RIB and SBS balanced good rutting and fatigue cracking performance while maintaining thermal cracking resistance comparable to that of control binder.

Base-Binder-Dependent Reactivity in Epoxy-Modified Asphalts (EMA) for Durable Open-Graded Friction Course (OGFC)

Michael Elwardany & Varun Veginati | ***Engineering & Software Consultants, Inc.***
Adrian Andriescu | ***SES Group & Associates, LLC.***
Raj Dongre | ***Dongre Laboratory Services***
Nusnin Akter, David Mensching, & Jack Youtcheff | ***FHWA***

Several state Highway Agencies (SHA) are interested in utilizing Open-Graded Friction Course (OGFC) as a paving surface mix for various safety and environmental benefits. The predominant failure in OGFC is raveling, which results from long-term aging of the binder, which contributes to the loss of adhesion with aggregates. Epoxy-modified asphalt (EMA) technology is proven to increase asphalt durability and resistance to deformation, failure, and long-term oxidative aging. Thus, EMA may provide a solution to enhance the durability of OGFC and allow SHA to achieve safety, performance, and environmental goals. EMA field sections in New Zealand and the Netherlands have shown promising and superior performance. Epoxy is a reactive modifier and it is well-documented in the asphalt literature that reactive modifiers are highly-dependent on base-binder chemistry from the reactivity, effectiveness, and performance stand points. This study evaluates the base-binder-dependent reactivity of EMA. Additionally, the study provides a proof of concept for how the blend's reactivity can be optimized by changing the relative concentration of Part B (fatty acids and asphalt flux). This study is part of a larger effort to advance the knowledge and state of practice of EMA technology to achieve successful field trials in the USA.

Session 2 - Chemistry & Chemical Modification

Atomic Force Microscopic Imaging and Role of Reactive Isocyanate-Based Modifications on SBS-Modified Asphalt Improving Thermal Stability and Mechanical Performance

Khare, Ting, Buehler | *MIT-LAMM*
Debellis, Orr, Jourdan, Malonson | *BASF Corporation*

Samples of asphalt modified with and without rubber and reactive isocyanate were characterized by AFM and STEM to determine if individual components could be distinguished among the bitumen matrix. Initial investigations failed to resolve rubber and ISO-treated samples in bulk asphalt samples using surface AFM, and asphalt samples were found to be too soft for ultramicrotomy at room temperature. By cooling samples to sub ambient temperatures microtomed thin sections could be generated that could be imaged using light microscopy and consequently stable enough to perform AFM characterization without material coalescence. SBS rubber added to improve asphalt elasticity was successfully imaged using TappingMode™ AFM but became less visible when the asphalt was treated with reactive isocyanate despite evidence of improved elasticity. Semicrystalline surface domains were observed in all samples that are suspected of being a wax component. Bee-like structures normally observed in asphalt were not observed in microtomed thin sections or bulk samples modified with rubber and reactive isocyanate. An interesting consequence of the Covid-19 Pandemic resulted in samples being left in ambient conditions for three month and found to undergo spinodal decomposition and show increased modulus values (GPa) relative to fresh samples (MPa) using PeakForce™ QNM™ AFM.

Fractionation and Characterization of Asphalt using Advanced Mass Spectrometry Techniques in Conjunction with NMR and IR Characterization

Junho Jeon, Hayley Brown, C. J DuBois, Anthony P. Gies, Dan Baugh III, Anna Leal, Praveen Boopalachandran, David Meunier, Skylar Ballinger, Ilia Kobylianskii, John Stutzman | *Dow Inc.*

Variability in crude sourcing and refining procedures results in asphalts with greatly variable chemical composition, making it difficult to predict fresh and aged performance for paving binders. A variety of polymeric systems, including Reactive Elastomeric Terpolymers (RET), have been developed to improve physical and mechanical properties in asphalt, but it is well known that the variation in asphalt composition affects the performance for many types of polymer-modified asphalt. The presence of active hydrogen groups (e.g., -OH, -SH, -NH2) contribute to hydrogen bonding and polarity, impacting physical properties such as solubility and mechanical performance. Quantitatively measuring the active hydrogen concentration in asphalts is not straightforward, especially with respect to concentration vs molecular weight or carbon number. Advances in mass resolution for high resolution mass spectrometry make it possible to generate increasingly accurate maps of functional group content, albeit with sensitivity to sample preparation and data processing. This talk will highlight the value of comparative ultra-high resolution Fourier-transform mass spectrometry characterization before and after standard SARA separation to illuminate the distribution of functional groups within these solubility-based fractions.

Session 2 - Chemistry & Chemical Modicication

Evaluation of the Relationship between Rheological Properties and Functional Group Indices for Asphalt Binders from Mixtures Treated with Recycling Agents (RA)

Runhua Zhang, Jo E. Sias, & Eshan V. Dave | ***University of New Hampshire***
Andrew Hanz, & Gerald Reinke | ***MTE Services Inc.***

Ten plant-produced mixtures were evaluated including three control mixtures (with RAP only) and seven RAP mixtures treated with different RA products. Corresponding binder samples were extracted and recovered from mixtures and were then subjected to 20-, 40- and 60-hours PAV aging conditions. Temperature and frequency sweep tests using a Dynamic Shear Rheometer (DSR) (with 4, 8, 25mm plates) were performed on these binders and the measured binder PG grades and rheological indices (e.g. binder Glover-Rowe (G-R), R-value and .Tc) were used to evaluate the change of binder rheological properties with aging. The Fourier-transform Infrared Spectroscopy (FTIR) analysis was conducted and calculated functional group indices (carbonyl peak/area and sulfoxide peak/area) were used to characterize changes in binder chemical properties with aging. The relationships between binder rheological and chemical properties were investigated. Results show that addition of RAs can significantly improve the properties of asphalt binder before long-term aging conditioning. Some RAs decrease the aging resistance of binder samples. Further, it was observed that to better characterize the effect of RAs on binder properties, traditional FTIR analysis needs to be improved by increasing the sulfoxide peak region to lower wavenumbers while moving or extending the carbonyl peak area to higher wavenumbers.

Evaluation of Bio-Based Recycling Agents

Raquel Moraes | ***NCAT***

Phase I of this study screened five bio-based recycling agents (RAs) using Gas Chromatograph/Mass Spectrometry (GC/MS) and binder rheological properties at low temperatures measured with the Bending Beam Rheometer. Considering that the overall stability of the fatty acids on each bio-based RA is governed by physicochemical factors related to the state of dispersion of the molecular microstructure rather than the inherent reactivity of the molecular components with oxygen, a fatty acid index (Delta fatty acids) was calculated for each additive. Based on collected results, a bio-based RA with the highest improvement in performance and another with the least were selected for further evaluation. Phase II included blending of the two bio-based RAs with two asphalt binders and reclaimed asphalt binder (RAP), and subjecting the resultant rejuvenated recycled binder blends to extend aging using the Pressure Aging Vessel. Rheological and chemical tests were conducted, including PG grading, Multiple Stress Creep Recovery, Linear Amplitude Sweep, Fourier Transform Infrared Spectroscopy, and Gel Permeation Chromatography. Results indicated that higher binder relaxation properties were obtained when using bio-based RAs with smaller Delta fatty acids index, since the type of fatty acids as well as the amount of unsaturation directly impact the performance of a bio-based RA.

Session 2 - Chemistry & Chemical Modicication

The Use of Soybean Oil-Derived Modifiers for Improving the Properties of Asphalt Pavements

Ali Arabzadeh, Ph.D., Joseph H. Podolsky, Ph.D., Maxwell D. Staver, R. Christopher Williams, Ph.D., Austin D. Hohmann, Nacú Hernández, Ph.D., & Eric W. Cochran, Ph.D. | ***Iowa State University***

Asphalt materials were prepared for two different pavement demonstration projects that occurred in the states of Iowa and Indiana. For reversing the undesired effects of reclaimed asphalt pavement (RAP) aggregate and increasing the rutting resistance, the asphalt materials were modified with soybean oil-derived modifiers. These modifiers were sub-epoxidized soybean oil (SESO) and poly (acrylated epoxidized high oleic soybean oil) (PAEHOSO). The SESO, being a reactive recycling agent was used to react with asphalt molecules, restore the asphaltene/maltene ratio, and prevent the premature failure of RAP-incorporated asphalt mixtures. The PAEHOSO, being a polymer, was used for developing large polymer networks in asphalt binders already modified with styrene butadiene styrene (SBS) to enhance the rutting resistance. To assess the effectiveness of the bio modifiers used, the binder properties such as continuous performance grades (PGs) as well as the elastic recovery (R) and non-recoverable creep compliance (Jnr) were measured. In addition, the mechanical performance of mixtures was evaluated using a Hamburg wheel tracking (HWT) device and a disc-shaped compact tension (DCT) machine. The results obtained revealed that the bio modifiers used in this study improve the rheological properties of binders and increase the resistance of mixtures to rutting and low temperature cracking.

Session 3 - Physical Testing Characterization

Performance Testing of Asphalt Mastic

Johannes Büchner & Michael P. Wistuba | ***Braunschweig Pavement Engineering Centre (ISBS), TU Braunschweig***

Various laboratory tests are available to evaluate performance of asphalt mixtures in different temperature regimes with regard to resistance to low-temperature cracking, to fatigue, and to permanent deformation. However, these performance tests require huge time and work effort. This study gives evidence that the asphalt mastic (binder-filler -composite) significantly affects these performance characteristics. The Dynamic Shear Rheometer (DSR) is used to test asphalt mastic considering different test procedures: Relaxation Test to study resistance to low-temperature cracking, Fatigue Test to study resistance to fatigue, and Creep Test to study resistance to permanent deformation. Different test geometries (4 mm, 8 mm, and 25 mm) are used to respect the different temperature regimes. For any of the three temperature regimes observed, a distinct correlation was found between asphalt mastic and asphalt mixture which was then validated considering 18 laboratory-produced and 6 plant-produced asphalt mixtures. It was concluded, that performance testing of asphalt mastic using DSR is a most promising tool for optimizing asphalt mixture performance.

Highlighting the Potential of the Phase Angle Master Curve Through Multivariate Statistical Analyses for Clustering Aged Asphalt Binders

Rodrigo Shigueiro Siroma, Mai Lan Nguyen, Pierre Hornych, Tristan Lorino, & Emmanuel Chailleux | ***Université Gustave Eiffel***
Yvong Hung | ***Total Marketing Service***
Aurélia Nicolai | ***Spie Batignolle Malet***
Layella Ziyani | ***École Spéciale des Travaux Publics***

The fact that several asphalt binder specifications are traditionally grounded in rheology-based indexes emphasizes their potential for assessing the durability of binders. The phase angle has widely been recognized as a powerful indicator due to its high sensitivity to changes that occur in binders with aging. Hence, this work focuses on estimating the aging level of laboratory and field aged binders using exclusively their phase angle master curves through two unsupervised multivariate analyses: Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA). In a two-dimentional PCA score plot, the studied binders are correctly projected according to their aging level, where a marked inflection point is detected along the path taken by each of them as they age. The studied binders were grouped into two clusters through HCA—one on each side of the inflection point—that correspond satisfactorily with the Glover-Rowe classification. The Delta Method was employed to determine the apparent molecular weight distribution of the studied binders based on their rheological response. The inflection point observed in the PCA analysis appears to be related to a considerable incidence of asphaltenes agglomeration, which in turn reduces the binder's ability to disperse stresses—thus making it more susceptible to cracking.

Session 3 - Physical Testing Characterization

X-Ray Tomography Imaging of the Pore Dtructure and Acoustical Properties of Low-Noise Semi-Dense Asphalt Field Samples

Peter Mikhailenko, Mateusz Wyrzykowski, Sahand Athari, Michele Griffa, Reto Pieren, Zhengyin Piao, Kurt Heutschi, Lily Poulikakos | *Empa*

Low-noise asphalt mixtures are increasingly common given the revelations on the effects of traffic related noise on human health. With the wide implementation of semi-dense asphalt (SDA) in Switzerland over the past decade, issues around the durability of noise characteristics have become apparent, resulting in the replacement of pavement surfaces due to the loss of low noise properties, rather than mechanical issues. In this study, X-ray tomography is conducted on field samples of SDA with 2-5 years of service life, with focus on the structure of porosity. This is combined with data on the mixture design and volumetrics of the mixture at placement and coring, along with the results of the sound absorption measured in the impedance tube and sound levels from statistical pass-by (SPB) measurements at the corresponding road sections. The understanding of the pore-structure is critical to implementing durable low-noise pavements.

Nanoscale Local Thermal Analysis of Bitumen Surface Microstructures

Farrokh Tarpoudi Bahri | *Empa & Laboratory of Thermodynamics in Emerging Technologies, Department of Mechanical and Process Engineering, ETH Zurich*
Peter Mikhailenko & Lily D. Poulikakos | *Empa*

Bitumen as an asphalt concrete binder is a complex material that typically, after the heating and quenching process, its surface microstructure develops three main domains: Catana, peri, and para. Atomic force microscopy (AFM) and AFM-IR analysis showed that the peri and para domains have different mechanical properties and chemical makeup. However, given that bitumen is a temperature-dependent material, it would be of interest to investigate the thermal property of each domain at a microscopic level. In the present study, we show the local thermal properties of bitumen surface microstructures using AFM nano thermal analysis (NanoTA). The applied voltage on the two arms of the NanoTA AFM cantilevers allows the controlled heating of the cantilever tip to 400 °C. The cantilever deflection due to substrate thermal response in contact with the heated tip reveals the thermal properties. Our results show that the deflection rate of cantilever versus increasing cantilever tip temperature in contact with the softer para domain is higher than, the stiffer peri domain. Subsequently, we present the effect of various polymer-based bitumen modifications on the surface topography, chemistry, and thermal properties.

Session 3 - Physical Testing Characterization

Aging Evaluation of Asphalt Recycling Agents for Hot Mix Asphalt – An Interlaboratory Study

Augusto Cannone Falchetto | ***Aalto University, Finland***
Martin Hugener | ***EMPA, Switzerland***
Di Wang | ***TU Braunschweig, Germany***
Laurent Porot | ***Kraton Chemical B.V., The Netherlands***

This study presents an overview of the core activity of the RILEM TC-264-RAP Task-Group 3 (Asphalt Binder for Recycled Asphalt Mixtures) which was performed by a group of 17 international laboratories (2015-2020). The goal of the research consisted in addressing the use of asphalt recycling agent (ARA) in combination with virgin and reclaimed asphalt (RA) binders and the associated aging phenomena. For this purpose, common ARA, virgin, and RA binders were selected and combined at three different recycling rates with equivalent RA content in asphalt mix: 60%, 80%, and 100%. Conventional (penetration and softening point), rheological (Dynamic Shear Rheometer), and chemical (FTIR) tests were performed to evaluate the behavior of the material under three different aging conditions: original, short- and long-term aging. The results confirm that the proposed approach is sufficiently robust to evaluate the aging behavior of the binder blends prepared with ARA, RA, and virgin binders in various combination. This is supported by the aging trends observed in the different blends compared to the reference binder based on conventional, rheological, and chemical characterization. As a result of this overall activity, a recommendation for an experimental protocol on the rheological evaluation of ARAs for hot mix asphalt is proposed.

Accelerated Pavement Weathering System (APWS)

Ken Grzybowski | ***PRI Asphalt Technologies, Inc.***
Gaylon Baumgardner | ***Paragon Technical Services, Inc.***

Evaluation of the effects of weathering on asphalt pavement mixtures is generally limited to laboratory thermal conditioning or full-scale field aging. The former is usually restricted to oven aging of loose mix in standard mixture aging for mechanical properties testing in mixture design and evaluation. Although on occasion compacted specimens or field cores are oven aged in order to evaluate specific mixture performance properties. Field aging also has limitations controlled by the consistency or lack thereof of the natural environment. Lacking has been a satisfactory metho9d to weather/age asphalt pavement mixtures which simulates actual field aging conditions. The Accelerated Pavement Weathering System (APWS) has been proposed to simulate temperatures, moisture, and natural radiation of pavement exposure. Presented is an overview of the APWS as proposed at the 2011 Pavement Performance Prediction Symposium (PPPS) with discussion of further development efforts and exemplary evaluation data in asphalt pavements and pavement preservations systems.

Session 3 - Physical Testing Characterization

A New Rapid DSR Separation Method for Polymer Modified Asphalt

Yuanchen (Simon) Cui, Saryn Vrij, Keith Stephens, & Joseph Bruns | ***U.S. Polyco***

The goal of this study was to develop a rapid test method on the Dynamic Shear Rheometer (DSR) to measure polymer modified asphalt (PMA) separation. Unlike the traditional aluminum tube test, this new method allows separation to occur while measurements are recorded on the DSR at the same time. Results could be reported within 1 hour. There are two main reasons why the aluminum tube test takes days. First, separation in PMA is a slow process. Second, if separation occurs, all the measurement methods, including Penetration, Softening Point, and DSR, require a sufficient amount of separation between the top and bottom of the tube due to the detection sensitivity and limit. Indeed, the DSR can perform extremely precise measurement and detect small changes in rheological properties caused by separation. Meanwhile, separation temperature can be controlled with strict precision. In this new DSR separation test, a regular DSR sample size (25 mm diameter) PMA was loaded and heated to 182.2°C (360°F) for 15 min. The complex modulus (G*) and phase angle (d) at 60°C (140°F) before and after heating were recorded. The difference of the phase angles has a linear correlation to the separation results measured by the aluminum tube method.

Thermally Induced Internal Cracking in Asphalt Mixtures – Validation and Prediction of Low Temperature Performance

Sang Soo Kim | ***EZ Asphalt Technologies***
Munir Nazzal ***University of Cincinnati***
Joshua Oklu | ***Ohio University***

The transition phenomenon observed in Ohio CTE Device (OCD) test of asphalt mixtures at low temperatures, ranging from -40C to -20C, is believed to be caused by thermally induced internal cracking. The objectives of this paper were to validate the thermally induced internal cracking using IDT strength test and to determine how the OCD transition temperature was related to the low temperature performance measured by TSRST and ACCD.
IDT strength tests were performed at -20C, -10C and 0C with several loading rates on three groups of samples: control, internally cracked, and healed groups. The control group was tested as-is while the internally cracked group was first subjected to -60C by cooling with 20C/hr rate to induce internal cracking prior to IDT test. The healed group was subjected to -60C and then to 25C for minimum 2 hours to heal prior to IDT test.
The energy input to reach the peak stress for the internally cracked group was up to 30% lower than the control group. The thermally induced internal cracks appeared to be completely healed by exposing to 25C for 2 hours.
OCD transition temperatures were highly correlated with TSRST and ACCD cracking temperature with r-square values greater than 0.95.

Session 3 - Physical Testing Characterization

What Doesn't Kill Asphalt, Makes it Stronger

Dr. Jean-Pascal Planche | ***Western Research Institute***
Dr. Gayle N. King | ***GHK, Inc.***
Dr. Michael D. Elwardany | ***Engineering & Software Consultants, Inc.***

Asphalt binder production and formulation have significantly changed since the SHRP program because of economic, technical, and environmental drivers. Although Superpave specifications rather successfully address binder properties that may lead to rutting, transverse cracking, and fatigue damage, aged-induced surface distresses have become THE challenge for highway agencies. Thermally-induced surface deteriorations appear in the form of traditional transverse cracking, block cracking, raveling, or accelerating damage at construction joints. They involve various damage mechanisms where external and internal restraints develop from differential contraction of asphalt mastic with surrounding aggregates as pavement surface cools. NCHRP 9-60 came up with a proposal for binder characterization and specifications based on the LVE index ΔTc from BBR and the new failure parameter DTf from BBR and ABCD. These parameters give credit to compatible binders either unmodified or modified. The project went further in the analysis of the composition, structure, molecular weight and thermal properties that impact the rheological and failure behavior. Glass transition in particular was confirmed as a major player. This paper emphasizes findings regarding chemical mapping and formulation guidelines to make asphalt stronger and not kill it, to lower glass transition, increase relaxation, strength and strain tolerance, eventually to improve pavement performance and durability.

Evaluation of Crossover Temperature and Aging Ratios to Evaluate Cracking of Binders

John D'Angelo | ***D'Angelo Consulting, LLC.***
Gaylon Baumgardner | ***Paragon Technical Services***

The use of DTc to evaluate the cracking potential of binder has increased significantly, with several DOT's including it in specifications. The DTc property has also put increased emphasis on aging to evaluate cracking, recommendations for longer PAV conditioning times have been made. The increase in PAV conditioning to 40 hours may capture binders that are prone to loss of relaxation. However, not all binders have significant loss of relaxation with 40 hour PAV. The problem has been associated with oxidized binder, RAS and some chemically modified like binders with high VTAE.
This study evaluated other properties of binders such as the Cross Over Temperature Twc to identify potential cracking issues and aging rations of rheological properties from RTFOT to 20 hour PAV to indicate if the binder may have issues with 40 hour PAV. This would limit the need for 40 hour PAV to only those binders that have poor aging ratios and an alternate to the extensive work needed to run the extra BBR samples. The findings show that the Cross Over temperature is a good alternate to the DTc and the binder aging ratios provide clear indications of potential issues of loss of relaxation with extended aging.

Session 3 - Physical Testing Characterization

Cracking Parameters of Asphalt Binders with Softener Modifiers

Javier J. García Mainieri, Punit Singhvi, Brajendra K. Sharma, & Imad L. Al-Qadi | ***University of Illinois Urbana Champaign***
Hasan Ozer | ***ASU***

The use of recycled asphalt pavement (RAP) materials has significantly increased the need for relatively softer asphalt binders to balance the aged stiff RAP binders. Various modifiers and additives have been developed to economically adjust the binder performance grade (PG). Long-term performance of two softener-modified binders having the same PG could be different. In this study, binders with softeners were tested, after extended aging periods, at a range of small- and large-strains.
The linear amplitude sweep (LAS) test was used to characterize the damage tolerance of asphalt binders. Current LAS data interpretation methods have drawbacks; hence, an alternative method was developed. The parameter (.|G*|peak t) was introduced to describe the reduction in measured complex shear modulus until the peak shear. .Tc, GRP, GRPf (from NCHRP 9-59), phase angle at |G*|=8967 kPa, and crossover parameters were obtained. This allowed detecting the effect of modifiers such as vegetable oil, fatty acids, and glycol amine on binders' rheological parameters. It was found that binder modified with ReOB behaved significantly different than other modified binders. This study also shows that the intermediate-temperature small-strain behavior of binders could be predicted using low-temperature small-strain parameters.

Automatic Pavement Condition Evaluation and Map Visualization (Case Study in Missouri)

Dr. Hamed Majidifard, Prof. William Buttlar, & Prof. Yaw Adu-Gyamfi | ***University of Missouri***

Pavement distress inspections are performed using sophisticated data collection vehicles and/or foot-on-ground surveys. In either approach, the process of distress detection is human-dependent, expensive, inefficient, and/or unsafe. In this study, a tool was developed by implementing various machine learning and deep learning techniques for distress detection and pavement condition ranking. This tool offers some advantages over traditional pavement monitoring (expensive cost of ARAN vehicles and laser equipment) and previous deep learning-based models. First, this tool excluded the dependency of pavement evaluation to human judgment and made it more accurate. Also, this software is the pioneer in concerning developing a prediction pavement condition index after developing a model to detect the distresses. Second, the models were developed based on a comprehensive pavement image dataset, which was annotated considering a wide variety of common pavement distress types by pavement experts. For case study, over 25000 google street-view images were used to evaluate the pavement condition of streets in the city of Columbia, Missouri. Finally, these first-generation models appear to have an acceptable average prediction error suggests that it may be very useful for DOTs and road agencies as a means to evaluate road sections conditions.

Session 3 - Physical Testing Characterization

When Superpave Doesn't Work

Jia Lu, Manpreet Sethi, Bob Kluttz, & Gary Fitts | *Kraton Polymers*

The Superpave Performance-Graded asphalt binder specification system was developed thirty years ago in the United States. It does a relatively good job of specifying appropriate binder grades based on climate and traffic, especially in its latest iteration AASHTO M 332. Quite naturally, it was developed to cover climates common in the United States, which is mostly situated in middle latitudes and heavily influenced by the large North American continental land mass. However, there is a problem when applying the PG system to tropical or maritime climates, where there is little seasonal change in temperatures. In the United States, most LTPPBind 98% reliability grades have a Useful Temperature Interval (UTI) of 80 or higher. In Southeast Asia, however, common grades are PG 64+10 to PG 58+16 with UTIs of 54 down to 42. These are obviously not appropriate specification grades. Since this region does not experience cold temperatures, Bending Beam Rheometers (BBR) and Pressure Aging Vessels (PAV) are rarely used or available in the region. In this presentation, we will explore options for implementing an adjusted PG grading system to provide adequate permanent deformation resistance and still manage intermediate temperature rheological properties.

Session 4 - Plastics & Recycling

Morphology and Rheology of Asphalt Binders Modified With Different Amount of the PE/SBR Thermoplastic Volcanized Polymer

Mohammad Zia Alavi | ***School of Civil Engineering, Faculty of Engineering, University of Tehran***
Morteza Karbasi & Mahmoudreza Favakeh | ***Department of Civil Engineering, Science and Research Branch, Islamic Azad University***
Fatemeh Zoghi | ***Bitumen and Moisture Isolation Laboratory, Hesar Mehran Refinery***

In this study a 60/70 penetration grade asphalt binder was modified with a proposed thermoplastic vulcanized (TPV) polymer. The TPV composed of linear low density polyethylene (PE) and styrene butadiene rubber (SBR) at the weight ratio of 80:20. The asphalt binder was modified with two, four, and six percent. The results of cigarette bar tube tests showed that while storing, some of the fine TPV particles were conglomerated and moved to the top of the tube as observed by both florescent microscopic photos and softening point measurements. The storage stability of 4% TPV modified binder was in acceptable range. Preliminary results of DSR test showed that the phase angles of modified binders at high in-service temperature were lower than that of the base binder, showing enhancement of elastic properties. The G*/sinδ of the modified binders with 2%, 4%, and 6% TPV at 64°C was 8, 11, and 12 times higher than that for the base binder. This resulted that the high PG of the base binder increased up to 86°C. Moreover, the results of multiple stress creep recovery (MSCR) tests revealed that the modification resulted in significant improvement in elastic recovery and considerable decrease in non-recoverable creep compliance values.

Dry-Process Recycled Plastics Modified (RPM) Asphalt Mixture Design and Performance Evaluation

Jean-Paul Fort | ***COLAS USA***
Fan Yin | ***National Center for Asphalt Technology***

Use of recycled plastics in asphalt has gained interest as an opportunity to improve the quality of asphalt pavements and help address the issue of waste plastics. Recycled plastics can be incorporated into asphalt using the "Wet" or the "Dry" process. A recent field demonstration project using dry-process recycled plastics modified (RPM) asphalt mixtures was constructed through the Asphalt Early Adopter Cohort efforts initiated by the Plastics Industry Association. After the recycled plastic source was selected, a performance-based asphalt mix design was conducted where the virgin binder grade and plastic dosage were adjusted to (1) balance rutting resistance using the HWTT with low-temperature cracking resistance using the TSRST and (2) match the performance properties of the SP12.5 70-22M control mix. Both mixes were further characterized for their cracking resistance using the IDEAL-CT and the ACCD test. Production and construction entailed no other additional constraint than meeting the required production and placement temperatures and the adaptation of a metering unit for warranting the accuracy and consistency of dosage of the recycled plastic. Control and RPM mixes were sampled for mix design validation, which will be further evaluated through a comprehensive performance testing under NCHRP Project 9-66.

Session 4 - Plastics & Recycling

Use of a Chemically Modified Recycled Plastic Additive for Asphalt Modification

Fan Yin | *NCAT*

Because of the potential environmental and performance benefits, the asphalt pavement industry is becoming increasingly interested in the use of recycled plastics in asphalt. Although recycled plastics can be added to the asphalt binder via the wet process, this process is challenging because the resultant modified binders are highly susceptible to phase separation and cracking issues. One effective approach to overcome this limitation is to chemically modify recycled plastics to improve their compatibility with the asphalt binder. This study sought to explore the use of a specifically engineered recycled plastic additive (i.e., CERANOVUS® A115) for asphalt modification. CERANOVUS® A115 is a value-added polyethylene wax additive that is 100% derived from post-consumer recycled plastics. Asphalt binder testing results indicated that the A115 modified binders had superior storage stability and morphology. Furthermore, the additive showed an overall stiffening effect on the base binder. Mixture performance testing results indicated that using hybrid A115/SBS modified binders improved the rutting resistance, intermediate-temperature cracking resistance, and fatigue damage characteristics of the control mixture. Finally, theoretical pavement structural analysis indicated that the hybrid binder formulations enhanced the structural capability of asphalt mixtures and thus, are expected to provide significant cost savings from a pavement thickness reduction perspective.

Binder and Mix Performance of Wet Process Polyethylene-Rich Recycle Streams with an RET Compatibilizer

C.J. DuBois & Cristina Serrat | *Dow, Inc.*
Fan Yin | *National Center for Asphalt Technology, Auburn University*

The incorporation of polyethylene-rich (PE) recycled streams as asphalt modifiers has had high interest, but historic efforts to meet performance graded asphalt specifications have been challenging for plastomers. The National Asphalt Pavement Association (NAPA) has published key points regarding knowledge gaps and future research to address challenges for these systems, including types of recycled plastic and performance vs. current modifiers. Part one of this presentation will share the use of a Reactive Elastomeric Terpolymer (RET) modifier to compatibilize #2 and #4 recycled plastics and meet AASHTO M320 and M332 performance criteria. Part two of this study compares PE-rich stream with RET, SBS, and unmodified asphalt based on Balanced Mix Design (BMD) testing and theoretical pavement structural analysis. The PE-rich stream with RET exhibited similar BMD performance to an SBS modified system and improved performance over the unmodified system.

Session 4 - Plastics & Recycling

Effect of Reactive Ethylene Terpolymer on Recycled Polyethylene Modified Asphalt Binder and Mixture

Helmut Leodarta, Punyaslok Rath, & William Buttlar | ***University of Missouri-Columbia***

The reutilization of waste plastic in asphalt binder has become a popular field of research inquiry as the global scientific community looks to find avenues for the effective recycling of waste plastic. The motivating factors behind reutilizing waste plastic in asphalt include reducing the environmental impact of waste plastic, and realizing potential economic savings due to performance enhancement, as shown in the early research studies. There are currently several key remaining challenges to overcome before the widespread deployment of waste plastic in asphalt pavements can occur. For instance, the addition of widely available Polyethylene (PE) to the asphalt binder, often results in issues with binder storage stability, due to its differing density as compared to the asphalt binder, and its non-polarity and inert nature. This issue was demonstrated in prior research, where PE pellets were used in asphalt binder modification. Considering the fact that smaller particle sizes usually improve storage stability in modified asphalt binders, this study investigates the use of powder-sized PE particles in asphalt modification. In addition, this study examines the effects of a Reactive Ethylene Terpolymer (RET) on the storage stability of the PE-modified binder. The study determined that the use of PE-Powder in asphalt binder improved the storage stability as compared to pelletized PE by at least 30% in terms of its effect on the DSR-determined high temperature performance grade (PG). Addition of RET further improved storage stability measured in this manner by at least 25%. Finally, mixture performance tests were also conducted on all mixtures made with the following binders- unmodified, PE-Powder modified, PE-Powder-RET modified, and RET modified. The Hamburg Wheel Tracking Test (HWTT) and Disc-shaped Compact Tension Test (DCT) were performed to ascertain the rutting and cracking potential of the mixtures. Improvements to both high and low temperature mixture performances were found in most of the formulations considered.

Deconvolution Analysis of Glass Transition Response to Aging and Rejuvenation

Hassan Tabatabaee & Tony Sylvester | ***Cargill***

The present study investigates bitumen compatibility through use of amorphous material miscibility principles by assessing the number of discernible glass transition occurrences in the blend. A sample set consisting of different virgin, recycled, and rejuvenated binders at various aging levels were selected for this study. The binders spanned different apparent "compatibility" levels.

A quantification method was devised through the deconvolution of the modulated differential scanning calorimetry (MDSC) response, resulting in a number of apparently novel indices for assessment of bitumen compatibility. Efforts were made to create a consistent and reproducible analysis method, in an attempt to limit subjective qualification in the analysis.
Although such methods may not be practical as every-day specification tools, the results demonstrate the promise of the proposed parameters and analysis framework as a quantified analytical measure that may be used for validation of future relevant specifications.

Session 4 - Plastics & Recycling

Characterizing the Aging of Asphalt Binder Containing Recycled Materials Through Rheological and Chemical Analysis

Mohammad Rahman, John Harvey, Mohamed Elkashef, Liya Jiao, David Jones | ***University of California Pavement Research Center, Department of Civil and Environmental Engineering, UC Davis***
Jorge Gonzalez-Estrella | ***Civil & Environmental Engineering, Oklahoma State University***

Aging is an important phenomenon for asphalt concrete which leads to a reduction in the flexible pavement resistance to raveling, cracking and moisture damage. The binder's chemical and rheological properties are both believed to change with asphalt aging. Furthermore, the pavement industry has increased the use of recycled materials in constructing flexible pavement to preserve natural resources. The aged binder from recycled materials is expected to alter the binder properties and its aging characteristics. In this study, ten different binder blends containing 0 to 100 percent recycled binder with three different base binder types were considered to evaluate the change in the asphalt binder properties with aging. These binders were subjected to different aging conditions and their rheological and chemical properties were characterized using DSR and FTIR microscopy, respectively. It was found that the Glover-Rowe (GR) parameter captured the change in binder rheological property with aging more distinctively for different binder blends. A good correlation (R2 value of 0.88 to 1.00) was observed between binder chemical Carbonyl Area (CA) index and rheological properties (complex modulus, GR parameter, crossover frequency) for the same base binder type. This correlation was found to change with the change in base binder type. Finally, the asphalt mix laboratory rutting performance was found to correlate well with the blends GR parameter (R2 value of 0.88). Therefore, binder blends can be a great source in predicting the asphalt mix performance containing recycled materials.

Field Study of Sustainable High Performance Engineered Asphalt Concrete Mixtures

Phil Blankenship & Zack McKay | ***Blankenship Asphalt Tech and Training, PLLC***

The paving community has been challenged to produce sustainable asphalt mixtures by incorporating higher amounts of reclaimed asphalt pavement (RAP) while maintaining the same performance qualities of virgin mixtures or mixtures produced with lower percentages of RAP. The use of higher amounts of RAP provides a more sustainable and green solution. The use of RAP lowers the demand for the use of new aggregates and asphalt binders. This report outlines an approach that utilizes performance testing in a balanced approach (Hamburg Wheel Tracker and IDEAL CT) to engineer mixtures using an aramid polymer fiber and a bio oil that will allow a paving contractor to meet the performance requirements that an agency requires. Three field trials will be discussed that will show the results of a control mixture (conventional) versus an engineered mixture. The balanced mixture design approach (Hamburg and IDEAL CT) will show that engineered high RAP mixtures can perform the same or better than conventional mixtures. The three projects were constructed in 2020 so it may be possible to show one year field data as well, if cracking is present in any of the sections.

Session 4 - Plastics & Recycling

Critical Review of the Properties of the Recovered ALF Binders and the Connections with Pavement Performance: Six Years of in situ Aging in the Presence of RAP and RAS.

Adrian Andriescu | ***SES Group & Associates, LLC.***
Michael Elwardany & Varun Veginati | ***Engineering & Software Consultants, Inc.***
Nusnin Akter, David Mensching, & Jack Youtcheff | ***FHWA***

Roads are an essential part of the nation's infrastructure and a better understanding of pavements behavior and performance will lead to effective pavement design frameworks and improved pavement durability. The latest ALF experiment where RAP and RAS were present in various proportions in different lanes has opened the opportunity to evaluate the evolution of the binder properties during the six years loading experiment. This study explores the correlations between the fatigue performance of the mix and the rheological or failure properties of the respective recovered materials. Rheological parameters like the Glover-Rowe (GR) parameter (measured at 15°C and 10 rad/s), .Tc, the High and Low Temperature Performance Grades as well as strain tolerances, from the DENT test, were evaluated. Results indicated that the materials are going through a significant aging/embrittlement process due to long-term oxidative aging. Inside the top 1 inch of material the changes are more intense and there is a fairly good correlation between the recovered binder properties rankings and the fatigue performance of the mix as resulted through the accelerated loading process. However, the bottom layer of materials is not going through changes of the same magnitude and the respective correlations are much weaker.

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